

Rainfall patterns and population dynamics of *Aedes (Aedimorphus) vexans arabiensis*, Patton 1905 (Diptera: Culicidae), a potential vector of Rift Valley Fever virus in Senegal

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ABSTRACT: The importance of rainfall for the development of *Aedes vexans arabiensis* populations, one of the potential vectors of Rift Valley Fever in West Africa, was demonstrated in a two-year follow-up study conducted in the Ferlo region of Senegal. In 2003, the rainy season began with heavy rains and, as a result, temporary ponds, the breeding places for mosquitoes, were flooded at their maximum level immediately. In such conditions, *Aedes vexans arabiensis* populations are abundant at the very beginning of the season, when the majority of eggs in quiescence are flooded. Females, hatching from eggs laid the year before, quickly lay eggs on the pond's wet soil, which will undergo dormancy as the water level goes down. Rainless periods longer than seven days, the time needed for embryogenesis, followed by significant rainfall, will result in the hatching of very large numbers of new eggs. Thus, several generations of adults may exist during the same rainy season. Because of potential vertical transmission of Rift Valley Fever virus in *Aedes* species, viral transmission and disease risk can appear as early as the beginning of the rainy season and if late rains occur, at the end of the season. This dynamic maximizes the virus' chance to persist from one year to another, thus facilitating endemisation of Rift Valley Fever in areas where *Aedes vexans arabiensis* exists. **Journal of Vector Ecology 30 (1): 102-106. 2005.**

Keyword Index: *Aedes vexans arabiensis*, population dynamics, rainfall variations, Rift Valley Fever.

INTRODUCTION

A higher incidence of arbovirosis at each epizooty and an increasing geographical distribution are pertinent reasons for conducting studies on the bioecology of potential vectors. In West Africa, entomological and virological surveys conducted during the last decade have confirmed the circulation of Rift Valley Fever virus (RVFV) in Senegal (Wilson et al. 1994, Thiongane et al. 1996, Zeller et al. 1997), and in 2002 and 2003 in the Ferlo region (EMPRES 2003), and the potential role of *Aedes vexans* as a vector (Fontenille et al. 1998). The Ferlo area, a pastoral region, is a fossil valley of roughly 60,000 square kilometers. Its hydrologic network communicates with Lac de Guiers and the lower basin of the Senegal River. Ponds existing in the low bed of the fossilized Ferlo River and its secondary arms are all temporary, their filling dependent on rainfall. These collections of free water, important watering places for livestock and the domestic activities of human populations, are the center of local ecosystems where arboviral and parasitical disease vectors often proliferate.

The Ferlo area stretches between the 100 mm and 500

mm isohyets and has a Sahelian climate. The rainy season lasts 4 to 5 months (June/July to September/October), and more than 90% of the rainfall comes from squall lines (Ndong 1996; Sagna 2000). During the dry season, herds of domestic animals (cattle, sheep, and goat) concentrate around natural pools, the only places with free water. When the rainy season starts, several temporary ponds refill, and transhumant herds come to settle each year (Pin 2003).

In addition, these ponds are usually places where mosquitoes, mainly *Aedes*, *Culex*, and *Anopheles*, reproduce. *Ae. vexans*, represented by the *arabiensis* sub-species (Edwards 1941, Knight 1978, White 1975), lay their eggs at the water's edge, on the soil, or on the vegetation. The eggs become dormant after their embryogenesis and can therefore undergo a desiccation period of one week to several years before hatching when flooded.

Our study was part of a global project on Rift Valley Fever ecology in Senegal conducted in the district of Barkedji (14,87 W - 15,28 N) during the rainy seasons of 2002 and 2003, from July to November. Its objective was to describe the influence of rain patterns on the dynamics of *Ae. vexans arabiensis* female populations. The baseline hypothesis was

that after a given amount of rainwater, some of the eggs in quiescence, defined as an arrest in development due to adverse conditions such as lack of free water, could find suitable conditions to hatch. *Ae. vexans arabiensis* has a rapid larval development. Some previous studies conducted in the Ferlo area indicate that the time between rains and the trapping of the first adults is four days (Fontenille et al. 1998). Therefore, by trapping aggressive females daily, for at least ten days after a rain, it was expected there would be one initial abundance peak due to nulliparous females that have not yet laid eggs and then other peaks with older parous females that have laid eggs at least once. The distinction between nulliparous and parous females was made by dissection of the ovaries.

MATERIALS AND METHODS

The meteorological station of Barkedji kindly provided rainfall data for June, 2002. Data were collected from July to November in 2002 and 2003 using an automatic meteorological collector WM 918 from Skyview Systems Ltd. The human-landing bait technique was used for mosquito trapping. Six teams of two people performed mosquito collections from 6 to 10 pm when *Aedes* females normally feed. Human baits were sampled in three places: Barkedji village and two temporary settlements with their respective ponds, the distance between pond and village or settlement equaling approximately 500 m. Trapping was conducted during 10 consecutive days (except 13 d in July, 2002, 9 d in July, 2003 and 5 d in October, 2003), resulting in 77 trapping sessions in 8 periods in the course of the 2002 and 2003 rainy seasons. After species diagnosis, the ovaries of *Aedes vexans arabiensis* were dissected according to a method derived from Polovodova's (Mondet 1993) to determine their physiological age by the observation of the ovarioles. Females were classified into two categories: nulliparous and parous.

RESULTS

In Barkedji, the normal seasonal rainfall average (measured each year from June to October from 1961 to 1990)

is 398.6 mm. The annual rainfall in 2002 was 299.1 mm and was 379 mm in 2003, showing a marked deficit of 25% and 5%, respectively. The year 2002 was characterized by light rains in the first half of the season and late filling of ponds (mid-August). In reality, first rains do not always fill the ponds because water is first absorbed by the sandy soil. Previous observations indicate that about 20 mm of rainfall is necessary to maintain wet ponds with water lasting for at least one week (Anonymous 2002). In 2003, heavy rains occurring at the beginning of the season (for instance, the 73 mm in one rainfall recorded 28 June) prematurely filled up the ponds at their higher level. Intermittent rainfall during the seasons made it possible to describe the impact of each rainfall on the dynamics of *Aedes vexans arabiensis* population, by studying the distribution of the 5,758 females trapped (1,209 nulliparous and 4,549 parous) during all the trapping sessions. Although the profiles were different in 2002 and 2003, the variations in *Ae. vexans arabiensis* abundance can be linked with the rainfall.

To describe seasonal variations in abundance, the rainy season was divided into four periods: the beginning (June/July) and the end (August) of the first half, and the beginning (September) and the end (October/November) of the second half. At the beginning of the first half of the season, all the eggs laid the year before, submitted to desiccation for more than 7 mo and still alive, were ready to hatch. The number of resulting females, during the 10-d catching period was dependent on the amount of rainwater during the previous fifteen days, but the first rainfall had to be higher than 20 mm to create conditions lasting long enough for the development of the aquatic stages. Therefore, 427 females and 1,684 females were caught in July 2002 and July 2003, with respective rainfalls having reached 33 mm and 79 mm the previous 15 d.

Finally, at the end of the second half, rainfall decreased and the ponds progressively dried up. Although that situation existed in 2002, 654 females were trapped in October after a rainfall of 24 mm subsequent to a period of 18 d without rain. In October, 2003, 54 females were caught, in only 4-d trapping instead of 10, after a 37 mm rainfall following a period of 13

Table 1. Comparison between 2002 and 2003 numbers of collected females during ten days in relation to rainfall during the 15 preceding days (Ferlo area, Senegal, 2002 and 2003).

Period	Year	Rainfall (mm)	Number of nulliparous females	Number of parous females	Total number of females
June/July	2002	33	43	384	427
	2003	79	524	1160	1684
August	2002	93	123	613	736
	2003	51	66	1613	1679
September	2002	58	20	178	198
	2003	71	30	296	326
Oct/November	2002	24	373	281	654
	2003	37	30	24	54*

*4-day period.

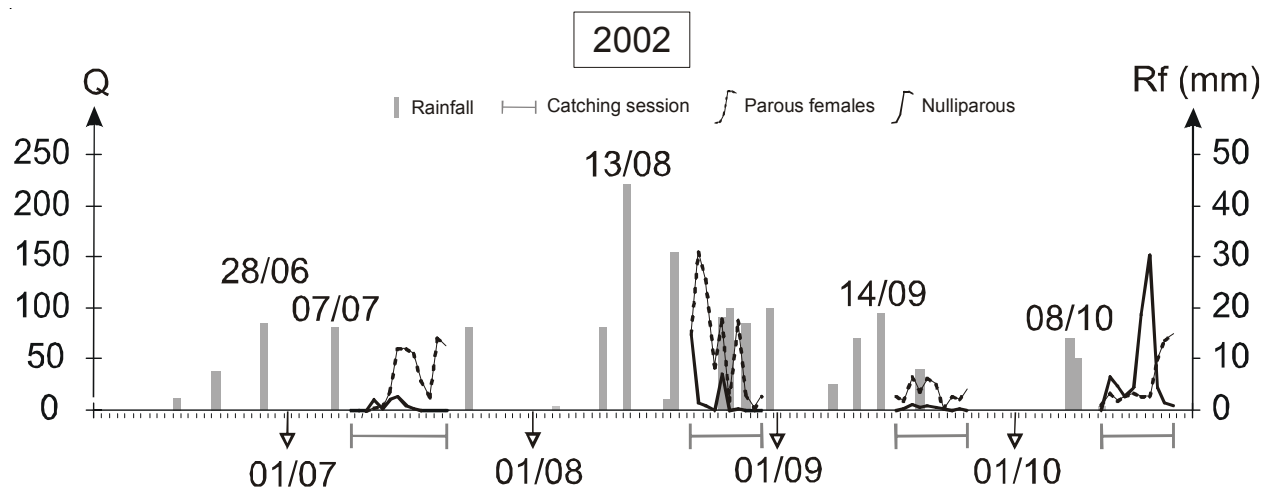


Figure 1. Rainfall (Rf) and daily abundance (Q) of *Aedes vexans arabiensis* females in Barkedji region, Ferlo, Senegal, during the rainy season, 2002.

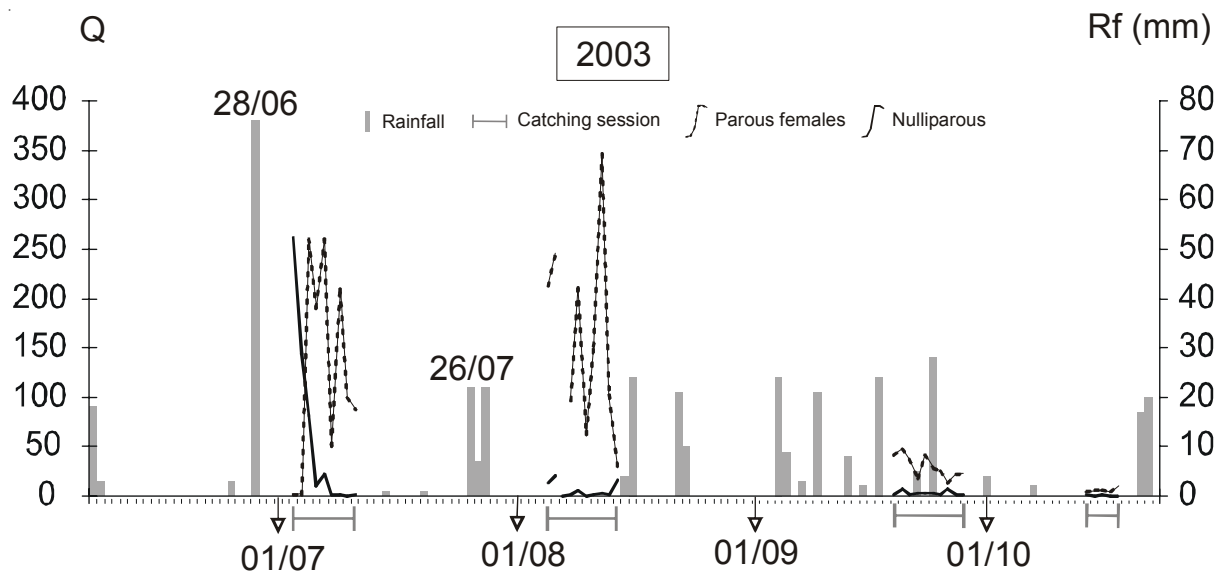


Figure 2. Rainfall (Rf) and daily abundance (Q) of *Aedes vexans arabiensis* females in Barkedji region, Ferlo, Senegal, during the rainy season, 2003.

d without rain. So, the appearance of *Aedes* females is directly related to rainfall and to a period of dryness in the preceding days.

DISCUSSION

The nulliparous females observed 5 to 8 d after the rain derived from part of the flooded eggs laid on the surface of the pond. However, the relationship between the amount of rainfall and number of emerging females is not linear, and the bionomics of the *Aedes* mosquitoes might explain this. Immediately after being laid on the soil above the water level, a thick chorion appears, making the eggs resistant to desiccation, and embryogenesis continues for 5-6 d. The eggs will not hatch if they are immersed before embryogenesis occurs (Horsfall 1955, Sinègre 1974) and undergo quiescence until the next flooding, which can occur weeks, months, and even years later. At the end of the first half of the season, it may be possible that some of the eggs, laid the year before, remain unhatched despite immersion. In addition, the first-generation females lay new eggs. Thus, at the end of the first half of the season, after undergoing multiple gonotrophic cycles and hatching a series of eggs, a mixture of generations of females should occur.

At the beginning of the second half of the season, rains are still abundant and continuous, and balance the water loss in the ponds due to infiltration and evaporation (Diop 2004). In 2002 and 2003, during the two wk before collecting periods, no intervals longer than seven d were recorded in the rains. Such conditions are not favorable for hatching of the *Aedes* eggs and, consequently, only a few females were trapped. At the end of the rainy season, the water level in the ponds decreases rapidly and all the laid eggs are in quiescence but potentially able to hatch if flooded. If a rainfall arrives, as in early October, 2002, filling the bottom of the pond, many nulliparous females will appear but only during a ten-d period.

The regular observation of Culicidae in Sahelian temporary ponds, such as those of the Ferlo area, confirms their capacity for resistance in temporary unfavorable conditions (dry season). In the genus *Aedes*, eggs can undergo what we simply called "quiescence", a phenomenon induced by environmental conditions (Denlinger 1986), even if it is certainly much more complex than a simple reaction to the lack of free water. These eggs, then, hatch a few months later once immersed. The most efficient stimulus for the hatching of eggs is the decrease of oxygen in rain water that may occur when water comes into contact with the soil either slowly, in less than half an hour if temperatures are between 30°C and 35°C, or very quickly, in a few minutes if soil is moist and covered with bacteria (Sinègre 1974). Sudden variations of temperatures are also efficient hatching stimuli (Gerberg et al. 1994). Most of these favorable conditions for *Aedes vexans arabiensis* occur in the larval biotopes of Ferlo ponds: water deoxygenating and thermal shock since the external temperature can drop more than 10 °C when it rains. In the field, in tropical conditions, it may thus be possible that considerable egg-hatching takes place very quickly after immersion, even if *Aedes* eggs are usually described as

requiring several drying and immersions periods for hatching (Cornet et al. 1978), especially *Ae. vexans* (Breeland and Pickard 1964).

Egg harvests in Nebraska have clearly proved that the evolution of *Ae. vexans* populations are correlated to rain patterns, peaks of activity appearing 10 d after rains in the beginning of the rainy season and 20 d at the end (Janousek and Kramer 1999). The results of this study describe a shorter length of time. The time for minimum desiccation of *Ae. vexans arabiensis* eggs seems to be about 10 d making it a potentially multivoltine species, with its number of generations depending of the alternation of rainy and dry periods. Therefore, external weather conditions, particularly rain patterns, will determine the number of generations and the population abundance per annum. As this species is a potential vector of RVFV with a probable vertical transmission of the virus, certain years may be more favorable than others for virus transmission. The risks of disease might be higher in the situation where heavy rains are separated by lengthy rainless periods. If vertical transmission exists with *Ae. vexans arabiensis*, as is the case for other species of *Aedes* which are vectors of yellow fever (Mondet et al. 2002) or Rift Valley Fever (Linthicum et al. 1985), first generations of females, derived from the previous year's stock of eggs, may allow circulation of the virus at the very beginning of the season. This may also occur in the case of late rainfall, resulting in the emergence of huge numbers of infected *Aedes* females at a time when they are usually rare.

The potential succession of several generations of mosquitoes may favor occurrence of disease, with the involvement of other mosquito species. Depending on the ecological zone, the role of *Aedes* needs to be modulated. This species is more abundant in dry Sahelian ecosystems like the Ferlo ponds than in other places like the Senegal River Basin. Here, the RVF epidemics have also been described and may involve the permanent presence of *Culex poicilipes* known to be another potential vector of RVF (Diallo et al. 2000). Nevertheless, *Aedes* may have a key role in the maintenance of the RVFV in the Ferlo (Chevalier et al. 2004), thus contributing to the endemisation of the disease.

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